1. Living Walls That Last

Technological advances in recent years have allowed the living wall industry to flourish. Combining these innovative developments with comprehensive horticultural expertise has allowed the industry to move past previous limitations and concerns.

Living Wall systems such as Biotecture's hydroponic living wall embody these characteristics to precisely monitor the health of our walls for longevity and resilience. Biotecture has installed over 200 vertical gardens and we are currently working on Europe's largest living wall.

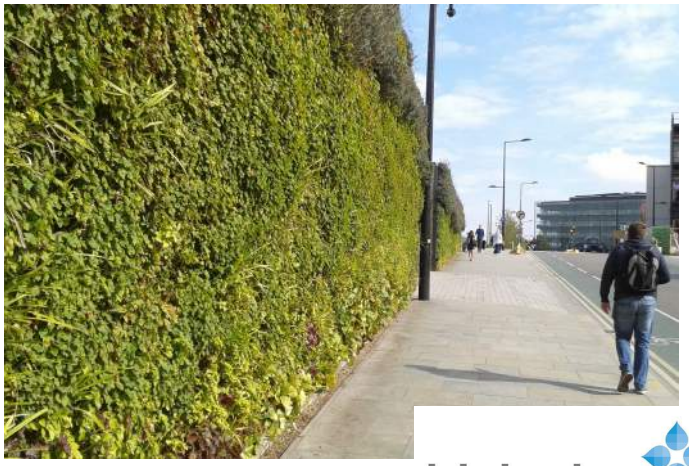
Dripline irrigation is used to precisely control the volume of water our living walls receive, whilst remote monitoring from our office allows the duration, frequency and timing of the irrigation to be meticulously regulated and adapted according to the needs of the plants throughout the year.

Biotecture have been supplying, installing and maintaining living walls since 2007. The long-term health of the wall is assured from the beginning, with maintenance and accessibility considered early in the design process.

The plant species are thoughtfully chosen to suit the characteristics of the wall, such as the location, aspect and microclimate, among others.

Extensive monitoring and trialling of plant species across the years has allowed us to establish the most successful species for living walls.

Following the installation, Biotecture will adhere to a Performance Specification and Maintenance Agreement . For an example see section 3.



Examples of hydroponic Living Walls in London. *Left*, student accommodation, Tower Bridge, *top right*, apartment block, Westminster, *middle right*, St. James Hotel, Buckingham Gate, *bottom right*, hoarding, King's Cross

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2. Living Walls: Client References

Hatton Place, London

Installed July 2008

"The living wall in the courtyard of our office has totally transformed the space we work in. It's going strong and we're currently working with Biotecture on several projects for living walls, which is itself an endorsement"

Michael Friel, Principal Architect, David Morley Architects, May 2014

New Street Square, London

Installed September 2011

"We recommend Biotecture because of the importance we place on selecting a supplier who has the expertise and commitment to design, install and maintain a successful large-scale green wall"

Neil Pennell, Head of Sustainability and Engineering, Land Securities plc, May 2014

Edgware Road Tube Station, London

Installed November 2011

"I've just stopped off to see the green wall and am pleased to report that it looks splendid!"

Nicola Cheetham, Head of Environment, Surface Transport, Transport for London, July 2014

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3. Performance and Maintenance Guarantees - to ensure that 95% of plants will be alive at all times

Adequate irrigation and regular maintenance are key to the success of the living wall. It is the absence of either or both of these factors that caused the issues with some of the pioneering living walls. Nowadays the industry includes remote monitoring of the irrigation system and robust maintenance plans to suit the characteristics of each individual wall as standard.

3.1 Performance Specification

Biotecture will be bound by a Performance Specification document, which will be specifically adapted to the individual project. The document is made up of stipulations regarding plant choice, irrigation and maintenance. An example Performance Specification is as follows:

Plant Choice

- Plants selected not only to satisfy the design requirements but also because they are generally available from wholesalers and are relatively interchangeable
- The species selected and any substitutes if necessary will be chosen such that they can survive in the conditions and in a hydroponic system and can be maintained at height

Irrigation Control System

- Automated
- Capable of supplying the correct amount of nutrients
- Controlled by a central control system; easy to read and understand, and accessible remotely by the operator
- Adaption of the watering system based on actual water content readings
- Ability to notify of blockages and/or leakages in a timely manner and with minimal intervention & searching for the problem
- Alarm to be raised when outside parameters
- Critical joints and pipes easily accessible
- Ability to measure the amount of water delivered to the wall and also to individual sections

Draft O&M

- Produced prior to service commencement
- Calendar and detail all standard maintenance and plant maintenance tasks
- Inspection procedure for structural elements
- Detail measures to be taken in the event of non-routine occurrences

Maintenance

- The living wall is to be designed and assembled to enable safe and easy access for cleaning, maintenance and parts exchange
- The maximum frequency of visual inspections of the wall is to be 28 days
- Wherever possible maintenance tasked shall be designed and engineered to be conducted from ground level
- Wherever possible natural biological controls are to be used

Key Performance Indicators

- **Irrigation system function = at least 95% of the times when it should function**
- **Visual aspect of wall = minimum 95% wall coverage by alive plants at all times**
- **The actual irrigation flow rate is within 20% of the design flow rates at all times**
- **Water consumption requirements = a maximum fresh water consumption of 2 litres per m^2 per day as an annual average**
- **Wastewater = a maximum waste water discharge of 0.2 litres per m^2 as an annual average**

3.2 Maintenance Agreement

As well as the Performance Specification, which guarantees the long-term health of the wall, Biotecture will work to the following Maintenance Agreement. The key points within the maintenance agreement are as follows:

Summary:

Maintenance, monitoring and upkeep of the green wall elements and ancillary plant

1. Statement of Intent

To signify the commitment of all parties both to this agreement and to the provision of sufficient resources to maintain the living green wall to a good standard at all times

2. Inspection & Reporting

Biotecture will make regular visual and photographic inspections of the green wall areas (all from ground level). These will be carried out at suitable prescribed intervals throughout the year.

Biotecture will carry out an annual close-up detailed inspection of all the areas of the green wall using access equipment. Biotecture will produce reports on standard forms of all inspections carried out. These will be formally issued to all parties.

3. Maintenance & Upkeep

3.1. Biotecture will carry out an annual maintenance of the green wall elements. This includes:

- Replacing (up to) 100% of the plants as necessary.
- Topping up the nutrients tank
- Tending of plants as necessary
- Maintaining the irrigation system

4. Pump(s) & Irrigation / Dosing System:

It will be the responsibility of Biotecture to ensure that the pumps and irrigation system are inspected and (where required) serviced at regular prescribed intervals as necessary.

It will be the responsibility of Biotecture to ensure that the dosing of the required nutrients is carried out at suitable intervals.

5. Remote Monitoring of the Irrigation System (if installed)

Biotecture will remotely monitor the irrigation controller on a regular basis during working hours with regard to expected values. Biotecture may remotely amend irrigation run times and irrigation program start times to suit the requirements of the plants.

Any exceptions to programmed or expected flows or any other observed anomalies will be investigated and resolved.

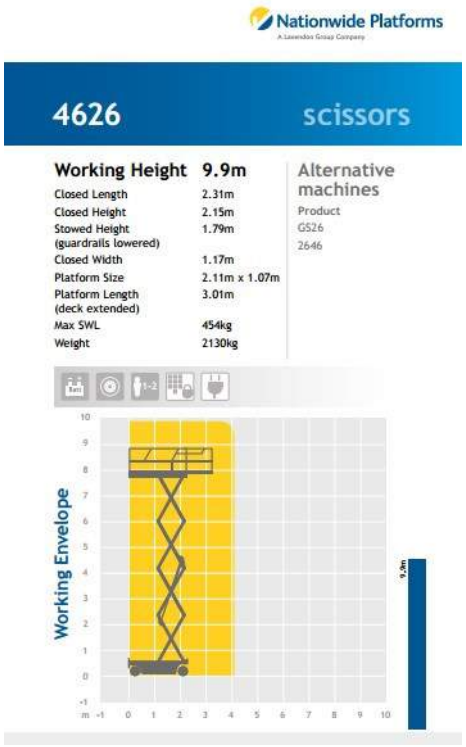
4. The Process

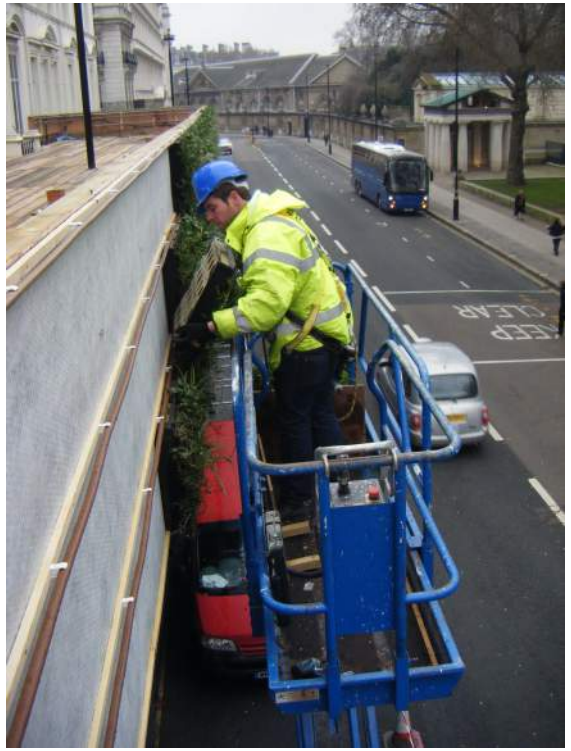
4.1.Horticultural Access

The horticultural maintenance visits to the living wall will be carried out via a mobile elevated work platform (MEWP). An example of a MEWP is shown here.

Full risk assessments and method statements will be produced and complied with to ensure that these works are undertaken in a safe manner.

Only trained and experienced operatives will carry out this work.





4.2. Synergy House Living Wall Maintenance Strategy

Ref	Maintenance Operation	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
GW 1	Monthly visual and photographic inspection of the wall	●	●	●	●	●	●	●	●	●	●	●	●
GW 2	Addition of Bio-controls to the irrigation system			●							●		
GW 3	Full access visit to prune / tidy / replace background planting as necessary				●		●			●			
GW 4	Daily check of the remote sensing irrigation log and moisture meters	●	●	●	●	●	●	●	●	●	●	●	●
GW 5	Monthly visual inspection of the irrigation plant room	●	●	●	●	●	●	●	●	●	●	●	●
GW 6	Topping up nutrient tank as necessary			●			●			●			
GW 7	Pressure test irrigation system plant room components			●									
GW 8	Strip, service and re-install dosing unit including by-pass until March										●		
GW 9	Take dosing unit off by-pass system and re-engage			●									
GW 10	Flush out all irrigation lines and check										●		

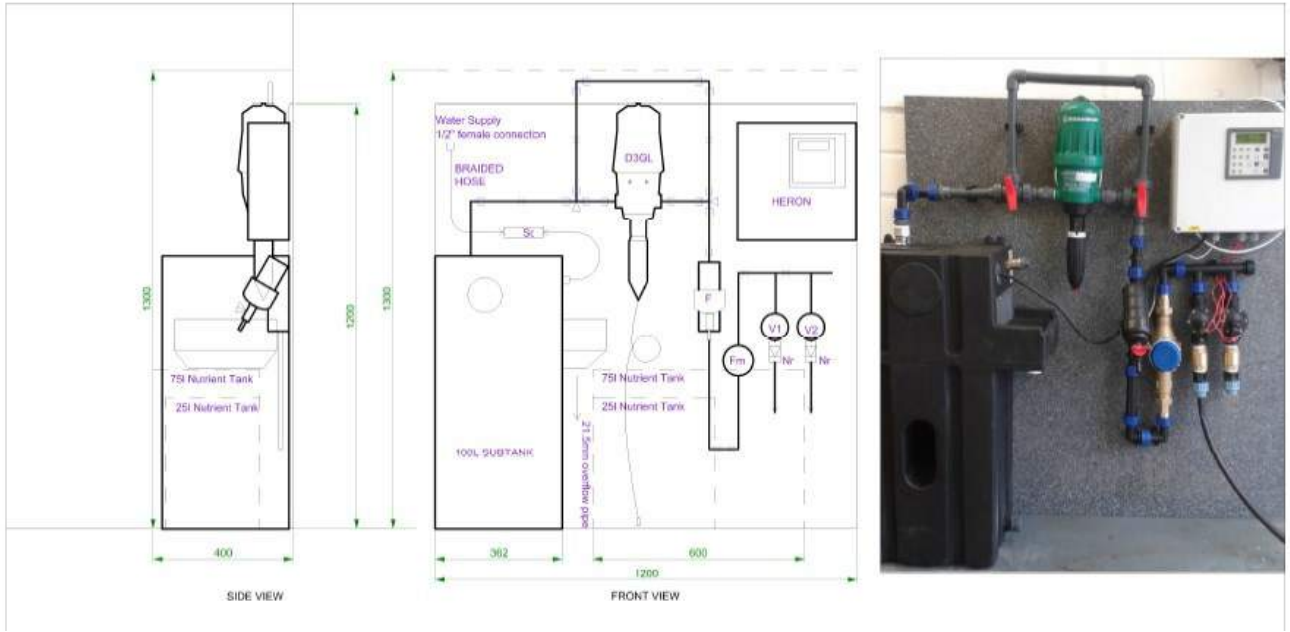
4.3. Irrigation System

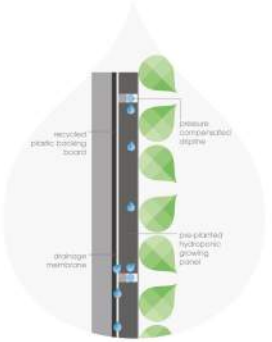
The living wall will be installed complete with a sophisticated irrigation system. An example of which is shown below.

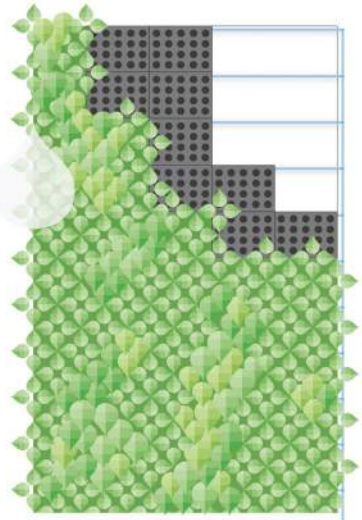
The controller will be programmed with flow-rate parameters for each zone and will be set to monitor the flow-rate at prescribed intervals (usually 30 seconds). It will also be set with a deviation percentage. When the controller monitors a flow-rate that deviates from the expected flow rate by more than the input deviation percentage it responds by, firstly, shutting off the pump instantly and secondly sending an alert message by email with a simple error message – i.e. “Valve 002 low flow fault.”

A flow-rate of 0 indicates a problem either with the incoming water or the pump. A flow-rate above zero but below the expected rate is rare. It most likely indicates that something needs to be cleaned out or flushed through – i.e. either an incoming filter or the drip-lines. A flow-rate in excess of the expected rate indicates a leak or pipe break downstream of the water meter. The logical location for the leak or pipe break will be at the pipe joints. These will all be recorded on the drawings.

Flow-rate is an extremely accurate measure of how an irrigation zone is performing. The flow-rate can be monitored at intervals as low as one second. Once the flow-rates have been established for the Southampton Row wall and have been monitored for a length of time, the flow-rate will be set at intervals of 30 seconds to avoid an overload of unnecessary data.







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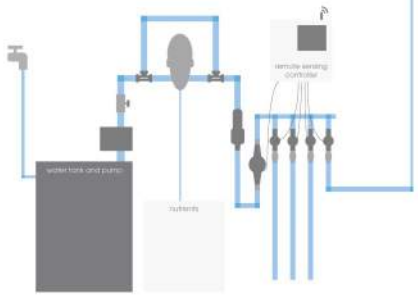
Transformational.



Precision Growing

HERON = Irrigation Controller
F = Filter
Fm = Flow Meter
V1, V2 etc = Solenoid Valve per zone
Nr = Non return Valve
= Three (3) way valves (Dosatron By-Pass Valves)
D3GL = Nutrient Dosing Unit
Sc = Magnetic Scale Inhibitor

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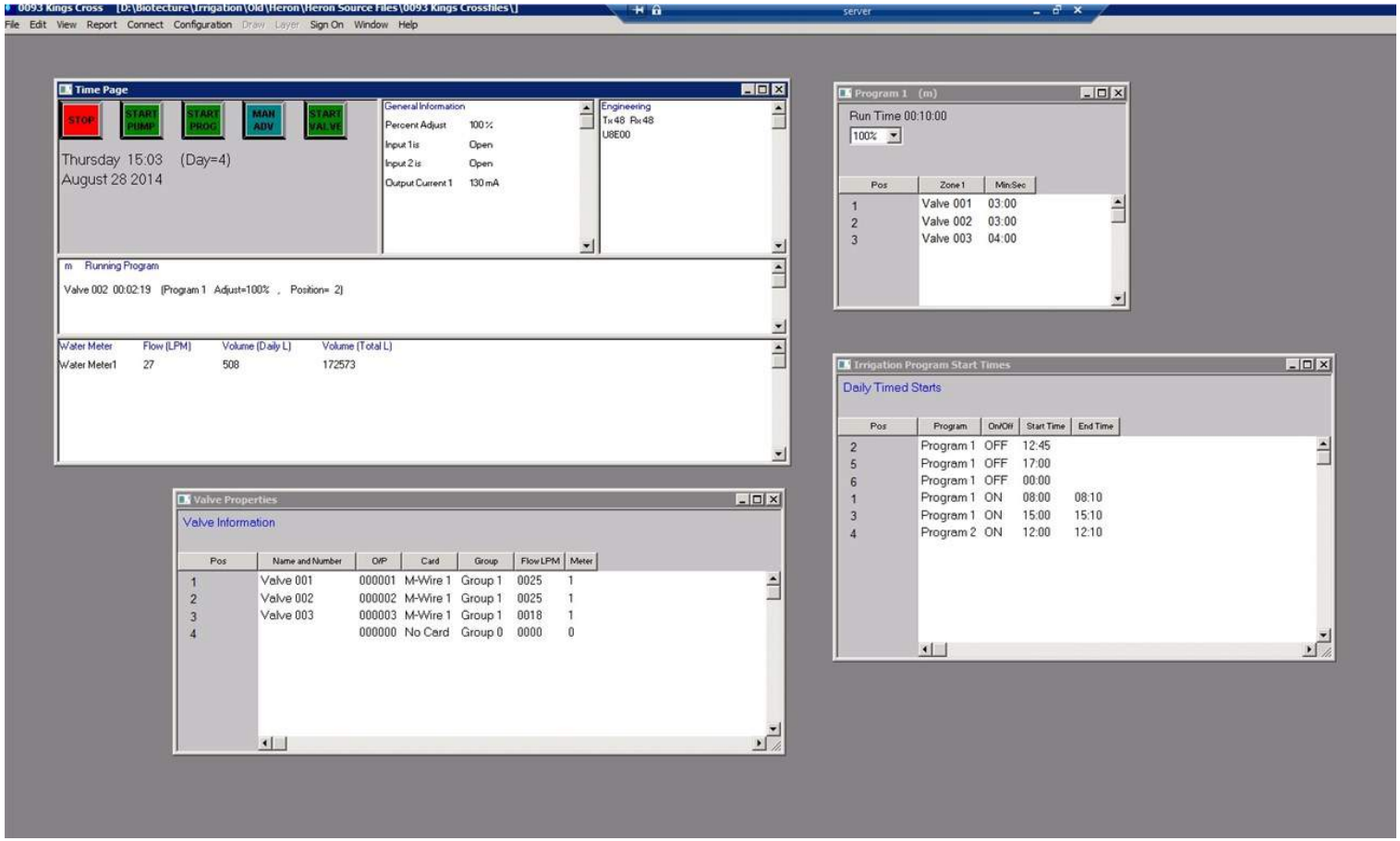
4.4. Remote Monitoring and Control

Remote sensing gives secure knowledge of what is happening to the living walls. The living wall systems are monitored remotely, meaning timings can be altered and in the event of a failure (too much or too little water being delivered), we are alerted by email and text message. The living wall will be monitored in this way.

Flow-rate is the best measure of performance for managing and reporting the irrigation system per irrigation zone. This is measured in litres per minute (lpm). When the pressure in the pipelines is maintained between 0.8 bar and 4.3 bar the drippers will each emit water at 1.6 litres per hour. The drippers cannot operate at any other flow rate than this. Each irrigation zone is clearly defined and the number of drippers in that zone can also be clearly defined. The expected flow-rate if all is operating correctly is therefore simply number of drippers x Drip Rate (1.6 litres per hour) and this can be closely monitored. The screenshot shows an example of the remote monitoring system in operation.



Every living wall is unique and reacts to its specific environment. A proper understanding of each living wall and its individual zones will be built by regular horticultural monitoring through the seasonal changes in the first year. The data obtained for each project on the changes made to the irrigation system through this period will be used to inform the anticipated parameters of a moisture sensing system for use in subsequent years.

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